Proposal for the Joint Development of an Atmospheric Model for use in Climate Modeling, Climate Assessment, Weather Prediction and Data Assimilation

Management Plan
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MP1. Management Overview

This proposal is to provide the resources to help build the infrastructure for joint model development at two of the United State's major Earth-science institutions. This infrastructure will be extensible so that other organizations can be included in the future. We propose to hire staff whose primary responsibility lies within the collaboration. This is critical for success. If the collaboration remains only one of several interests of well-intentioned scientists, then the benefits of the two organizations working together will not be realized.

The ultimate goal of this development will be the unification of global model development with the vision of a common model that can be flexibly configured to meet the specific requirements of the two organizations. This collaboration is motivated by the limited resource base faced by the U.S. modeling community, and addresses a number of the issues brought forward in the 1998 National Academy of Sciences, National Research Council, report *Capacity of U.S. Climate Modeling to Support Climate Change Assessment Activities.*

We recognize that such institutional collaborations are difficult, and a significant change in the normal way of business of U.S. science organizations. Therefore, we feel that an explicit investment in a joint infrastructure to support the collaboration is required. The tangible commodity of the collaboration is software. Given the computational challenges that face high-end modeling efforts, especially in the U.S., the robustness of the software is more critical than ever before. Therefore, much of the initial investment will be focused on management of software, software process, and the input and output data sets. This includes developing a test suite and validation criteria for different configurations of the model.

The following are the initial requirements that the two organizations agree to.

1) There will be a single jointly held software repository under the management of a web-based configuration management tool. There will be a commitment in the near term to develop a mechanism to manage the repository, including the process of defining standard model configurations and how changes to those configurations are controlled. This will include a regular schedule to unify development branches into the standard configurations.

2) There will be a commitment to undertake a systematic design of the joint model. This design will include members from all vested organizations and will include consideration of major interfaces such as the flux coupler in the Climate System Model and the analysis component in the GEOS data assimilation system. Further, computational issues will be considered directly in the design, including runability, maintainability, and performance in a distributed-memory multiple-processor computational environment. This needs to consider external factors of the computing environment so that the application software is minimally reliant on vendor-supplied platform middleware. This design will be reviewed by a panel that is not inclusive of the designers.

Both of these institutional requirements are at the very foundation of the collaboration. If these issues are not faced at this time, then independent development at the two organizations will assure that the effort is fractured. This will undermine the viability of substantive joint development at the beginning.

By more tightly managing the development of the software, we hope to achieve a better environment to take advantage of scientific expertise in the two organizations as well as across the broader scientific community. By the development of a documented and controlled environment for numerical experimentation, we intend to increase the scientific integrity of the process of model development. In this way, the necessary diverse experimentation, which is obtained only through engagement of the larger community, can be more effectively transferred back to the home organizations. If dispersed development takes place with known standard configurations, then externally built algorithms can be incorporated into the standard configurations with confidence that the algorithm testing by external developers is directly relevant to the core model development. Through a controlled development environment, we anticipate that more people will be able to contribute, more efficiently, to model development.

We recognize that the proposed model development is taking place within two institutions that have important commitments to a large user community. The Climate System Model (CSM) has initiated a process for determining important development paths of the CSM. It is our intention that this joint effort, and the related software engineering activities, both contribute to the development of the processes that govern CSM evolution. The vision of the CSM activities providing a community resource and community ownership of the model is consistent with the organizational goals of both institutions. We are committed to maintaining documented, open code to satisfy the customers of both institutions.

Already, there is involvement of Department of Energy scientists. The Department of Energy (DOE) has provided Dr. D. Rotman at Lawrence Livermore National Laboratory, with approximately 1.5 full time equivalents to investigate the expression of the model in a completely parallel computing environment. We expect DOE to become a full partner in the effort, looking particularly for expertise in software engineering and parallel computing. In addition, DOE will be involved in model applications and development through both atmospheric chemistry applications and greenhouse gas assessments. If the Accelerated Climate Prediction Initiative is ultimately funded, then this model would be proposed as a key element of that program.

Finally, the proposed effort is being integrated with the activities of the Ad Hoc National Modeling Infrastructure Working Group (S. Zebiak and R. Dickinson, Co-Chairs). Several of the Co-Investigators are active participants in this activity. Currently the Working Group is focused on developing standards and criteria for module exchange. We view the potential success of the working group's activities as an important element for furthering institutional collaborations.

MP2. Personnel and their Responsibilities.

Since this proposal is targeted to develop the infrastructure for a sustained collaboration, it seeks support for software experts that are not currently on staff at either institution. The scientists, who are listed as co-investigators on the proposal, all have a vested interest in the success of the effort. Their funding is primarily provided by their home institutions. Therefore, this proposal seeks funding for the new staff, and only minimal funding for Drs. Lin and Boville, who have the primary administrative responsibility for the proposal.

Dr. Shian-Jiann Lin will serve as Principal Investigator. Dr. Lin leads the model development effort within the DAO at GSFC. He is the point of contact for the execution of this proposal with the cognizant NASA Program Manager. He also serves as the responsible point of contact with NCAR. Dr. Lin is responsible for the overall management of the resources and achieving the goals of the proposal. His scientific expertise is in computational fluid dynamics, and he holds primary responsibility for the development of the dynamical core used in the joint model. Dr. Lin will be the NASA lead in the design of the model.

Dr. Richard B. Rood will serve as a Co-Investigator. His primary responsibility will be as liaison between NASA/DAO and NCAR/CGD. He will assure that software and scientific issues are both considered in the development of strategic directions of the proposal. Through his NASA role as point of contact on interagency modeling and supercomputing activities, he will co-ordinate the effort with the broader community. He will contribute to the design and strategic direction of the model development.

Dr. Byron A. Boville will serve as a Co-Investigator. Dr. Boville is the co-Principal Investigator of the Climate System Model, and the designated Group Lead for the Community Climate Model. He will be the responsible point of contact at NCAR, and will also have administrative responsibility at NCAR. Dr. Boville's scientific expertise is atmospheric dynamics and climate modeling.

Dr. David L. Williamson will serve as a Co-Investigator. Dr. Williamson has been the NCAR principal in the development of the prototype model. He has been involved in design of the existing model and controlled experiments for model evaluation. This will continue to be his role.

Dr. Philip J. Rasch will serve as a Co-Investigator. Dr. Rasch was one of the original collaborators on the project, and helped to design the initial control experiments. His primary role will be in the development of physics parameterizations; especially those associated with cloud processes. He will be a principal in the evaluation of model performance.

Dr. James J. Hack will serve as a Co-Investigator. Dr. Hack is expert in atmospheric physics and the integration of model components. He will be involved in experiment design and guiding the implementation of the physics packages in different configurations of the model.

Dr. Maurice L. Blackmon will serve as a Co-Investigator. His primary responsibility will be as liaison between NCAR/CGD and NASA/DAO. He will assure that software and scientific issues

are both considered in the development of strategic directions of the proposal. Through his contacts with interagency modeling and supercomputing activities, he will co-ordinate the effort with the broader community. He will contribute to the design and strategic direction of the model development.

MP3: Computational Issues

The primary computational needs for this effort will be provided by the home institutions independent of this proposal.

The institutional requirements in Section MP1 state:

> There will be a single jointly held software repository under the management of a web-based configuration management tool. There will be a commitment in the near term to develop a mechanism to manage the repository, including the process of defining standard model configurations and how changes to those configurations are controlled. This will include a regular schedule to unify development branches into the standard configurations.

The DAO has selected, through a benchmarking procedure, the configuration management tool *Dimensions*. This web-based tool will be tested for its utility in a scientific development environment. Assuming that the tests are successful, and that both institutions concur on the use of this tool, the DAO will commit to buying the necessary licenses for the collaboration. Licenses for expansion of use of the tool beyond the collaboration will be negotiated, but are expected to be the responsibility of the home institutions.

MP4. Task Schedule

<u>Tasks for Year-1</u>

Design and development of the web-based software repository for the collaboration:
Lead: R. Rood (NASA/DAO)

General software design and coding standard: Leads: B. Boville (NCAR/CGD), S.-J. Lin, and W. Sawyer (NASA/DAO)

Development of the hybrid MPI-openMP parallel version of the NASA/DAO finite-volume dynamical core: Leads: S.-J. Lin and W. Sawyer (NASA/DAO); D. Rotman (DOE/LLNL).

Development of the interface to DAO's Data Assimilation System: Leads: A. da Silva and S.-J. Lin (NASA/DAO)

Implementation and experimentation of CCM4 physics in both CCM4 and NASA/DAO's configurations (different horizontal and vertical resolutions): Lead: S.-J. Lin (NASA/DAO); J. Hack (NCAR/CGD), P. Rasch (NCAR/CGD)

Implementation and initial experimentation with the finite-volume dynamical core within the CCM and CSM framework: Lead: B. Boville (NCAR/CGD) D. Williamson (NCAR/CGD)

In-depth intercomparisons of the impact of dynamical cores on the climate simulations within the CSM framework: Lead: B. Boville (NCAR/CGD)

Tasks for Year-2

Development of a 62-level and 1-degree or better horizontal resolution "troposphere-stratosphere-mesosphere" joint model configuration suitable for DAO's PM-1 Data Assimilation System: Lead: S.-J. Lin (NASA/DAO)

Continued development, fine tuning, and experimentation of the joint model within DAO's data assimilation framework: Lead: S.-J. Lin (NASA/DAO)

Diagnostics of the performance of the joint model in numerical weather predictions: Lead: S.-J. Lin (NASA/DAO; additional resources will be drawn from R. Atlas's synoptic evaluation group)

Diagnostics of the performance of the joint model in climate applications: Lead: B. Boville (NCAR/CGD); J. Hack (NCAR/CGD), P. Rasch (NCAR/CGD)

Further development of the Gravity Wave Drag parameterization: Lead: B. Boville (NCAR/CGD)

Continued development and implementation of CCM4 physics (e.g., new PBL scheme, surface fluxes parameterization, and more general cloud overlap schemes). J. Hack (NCAR/CGD), P. Rasch (NCAR/CGD)

Implementation and fine tuning of the finite-volume dynamical core within the NCAR CSM framework: Lead: B. Boville (NCAR/CGD); D. Williamson (NCAR/CGD)

Tasks for Year-3

Further developments of the finite-volume numerical algorithms including possible experimentation with different grids (e.g., the cubed grid and the Fibonacci grids): Leads: S.-J. Lin (NASA/DAO) and D. Williamson (NCAR/CGD)

Further diagnostics of the performances of various physical parameterizations and dynamical core formulations in data assimilation and NWP applications: Lead: S.-J. Lin (NASA/DAO)

Potential collaborations with other operational centers (e.g., NAVY and NOAA) in operational NWP and hurricane track and intensity predictions: Lead: S.-J. Lin (NASA/DAO)

Further development of the CCM physics and the CSM: Lead: B. Boville (NCAR/CGD)

Explore extensions of activities to climate-system assimilation.

MP5. Budget

Since this proposal is targeted to develop the foundation for a sustained collaboration, it seeks support for software experts that are not currently on staff at either institution. The scientists, who are listed as co-investigators on the proposal, all have a personal stake in the success of the effort. Their funding is primarily provided by their home institutions. Therefore, this proposal seeks funding for the new staff, and only minimal funding for Drs. Lin and Boville, who have the primary administrative responsibility for the proposal.

The current proposal is seeking augmentation over existing efforts in order to build the foundation for the collaboration. Within each organization, there is already a team of people working on the model. The DAO is committed to the joint model for its next generation operational system. Dr. Lin supervises three full time equivalents in the model development. These people are funded out of the DAO's science budget, but are currently focused primarily on model software and data management problems, including the first steps of parallelization. Through combination with existing funding, the additional request for two people would allow adequate attention to both the scientific development and the initial issues of software infrastructure.

In Fiscal Year 99, The National Science Foundation (NSF) provided $200K to NCAR as an initial investment in this collaboration. This was part of a fast-track study to investigate the scientific viability of the effort. This funding is continuing, and has been used to hire a software engineer at NCAR, as well as support for scientists involved in model validation. This $200K is not included in the numbers below. This represents the only full time equivalent currently devoted to the effort at NCAR. Drs. Williamson and Rasch have been the most involved at NCAR, helping in model and experiment design, as well as diagnostics. In addition others at NCAR have invested in the launch of the project. This additional funding at NCAR would allow the formation of a core group committed to the joint model, with the responsibility of building and nurturing the links for the collaboration to work.

In addition to the activities at NCAR and GSFC, the Department of Energy (DOE) has provided Dr. D. Rotman at Lawrence Livermore National Laboratory, with approximately 1.5 full time equivalents to investigate the expression of the model in a completely parallel computing environment. We are currently integrating these resources into the overall management of the joint project. This overall management is the responsibility of R. Rood. The DOE funds are not included in the numbers below.

Budget sheets are attached in the format of each home institution. That salary estimates derived for the proposed new personnel are based on those determined from experience as necessary to attract software professionals. Travel requests are higher than normal as the distributed nature of the collaboration is dependent upon sustained communications.

The total budget requested of NASA by both institutions is

FY00	FY01	FY02	Total
$455.10K	$474.88K	$494.83K	$1,424.81K